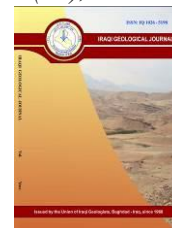




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Bryozoan Fauna from the Ora Formation (Late Devonian-Early Carboniferous) Within Selected Sections, in the Kurdistan Region, North of Iraq

Salam I.M. Al-Dulaimi¹ , Fatimah T. Abdallah^{2*} , and Mohammed D. Jaber³ 

¹ Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq

² Department of Information, Iraq Geological Survey, Baghdad, Iraq

³ Babylon Directorate of Education, Al-Farazdaq Secondary School for Boys

* Correspondence: fatima.talib88.ft@gmail.com

Abstract

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The Ora Formation in the northern part of Iraq constitutes a significant sedimentary archive of the Devonian–Carboniferous transition and is widely regarded as Famennian–Tournaisian in age. Despite its stratigraphic importance, the bryozoan content of this formation has remained insufficiently documented. The present study provides the first focused taxonomic investigation of bryozoans from the Ora Formation in the Ora and Nazdor sections, Duhok Governorate, northern Iraq, and assesses their systematic and biostratigraphic significance. The studied successions are composed of bryozoan-bearing carbonate interbeds alternating with shale, and the investigated material was analysed by field sampling and thin-section petrography under transmitted light. Bryozoans occur mainly in carbonate beds within the upper parts of the studied intervals and exhibit a variety of colony sizes, growth forms, and internal skeletal structures. The assemblage is moderately diverse and comprises more than ten taxa attributable mainly to the orders Trepostomata, Cryptostomata, Fenestrata, and Cystoporata, in addition to several forms retained in open nomenclature owing to preservational and sectional limitations. The identified taxa and their morphological affinities demonstrate close relationships with both Famennian and Tournaisian bryozoan fossils previously described from comparable extra-Iraqi successions. This confirms the importance of bryozoans as a reliable palaeontological tool for age assessment and regional correlation across the Late Devonian–Early Carboniferous interval. Accordingly, the present study establishes a new bryozoan-based taxonomic framework for the Ora Formation in the northern part of Iraq and provides a basis for future systematic, palaeoecological, biostratigraphic, and palaeobiogeographic investigations.

Keywords: Bryozoa; Ora Formation; Stenolaemata; Famennian; Tournaisian; Northern Iraq

1. Introduction

The Ora Formation was first recorded from the Northern Thrust Zone at the Ora Fold (Amadia, North Iraq) and is composed of black, fine, calcareous shales with olive-green, blocky silty marls, thin lentils of organic detrital limestone, and intermittent fine-grained sandstone, indicating a shallow-marine origin (Wetzel, 1952; Van Bellen et al., 1959). The upper contact with the Harur Formation is conformable and gradational, with the top of the Ora Formation marked by a sedimentary break (Van Bellen et al., 1959; Aqrabi, 1998). Palynological work from the northern part of Iraq DOI: <https://doi.org/10.46717/igi.2026.59.2B.6>

supports assigning the Ora Formation to the Late Devonian–Early Carboniferous interval (Famennian–Tournaisian) and notes that the age was debated historically but ultimately constrained by palynological evidence (Barzinjy, 2006; Aqrawi et al., 2010).

Regionally, the Ora Formation correlates with the Köprülü and Suke units in SE Turkey, Tournaisian mudstones of Jabal Abd al-Aziz and the Athar Formation in Syria, and the uppermost Jubah Formation in Saudi Arabia (Altinli, 1966; Ponikarov et al., 1967; Janvier et al., 1984; Al-Hajri et al., 1999; Clayton et al., 2000; Jassim and Goff, 2006; Al-Shammary and Kurkchi, 2015).

The Northern Ora Thrust Zone widens westward into three domal culminations (Sinat, Kaista, and Ora), where asymmetric folding and reverse faulting locally invert stratigraphy and influence the exposure quality at Ora and Nazdor localities (Jassim and Goff, 2006).

The present study is confined to two surface sections within the Imbricate Zone along the Iraq–Turkey border: (1) Ora section near north of Ora village, Amadia, at 37°17'50"N–43°20'15"E with ~75 m exposed thickness, and (2) Nazdor section west of Ora village at 37°18'10"N–43°08'15"E with ~160 m exposed thickness.

Bryozoans are a major Paleozoic benthic Phylum with high preservation potential due to their calcitic skeletons, and they provide valuable information for paleoecology, paleogeography, and biostratigraphy (Tolokonnikova and Ernst, 2017). The morphology is complex and commonly requires extensive thin-section preparation (Ernst et al., 2012).

Notably, bryozoan-rich grainstone/packstone microfacies occur within the upper unit at Nazdor section, attesting to fossil abundance suitable for systematic study (bryozoa and associated bioclasts) (Dunnington et al., 1959; Buday, 1980) and high-energy shoal deposition on an inner- to mid-ramp (Barzinjy, 2006; Aqrawi et al., 2010).

Importantly, the Late Devonian–Early Carboniferous interval represents a pivotal evolutionary transition in bryozoans: trepostomes lost their dominant position across the Devonian/Carboniferous boundary and were replaced by fenestrates, while the latest Famennian turnover is linked to the Hangenberg Event and is followed by the Early Carboniferous radiation (Tolokonnikova and Ernst, 2017).

Therefore, documenting the bryozoans of the Ora Formation contributes to taxonomy and age control (Famennian–Tournaisian) but also to regional correlation and understanding of fossil change across this globally significant interval (Ernst et al., 2019).

Accordingly, this research applies thin-section-based taxonomy and current systematic frameworks (including Stenolaemata/Palaeostomata usage in the Mississippian bryozoan studies) to document the bryozoan fossils from the Ora and Nazdor sections (Fig. 1).

2. Materials and Methods

Rock samples were collected from the carbonate intervals of the Ora Formation, which is exposed in two surface sections in the northern part of Iraq. The first locality is the Ora section near north of Ora village (Amadiya area, Duhok Governorate) at 37°17'50"N, 43°20'15"E, where ~75 m of the formation is exposed in the section, whereas the lowermost and uppermost parts are locally covered by Recent sediments. The second locality is the Nazdor section west of Ora village at 37°18'10"N, 43°08'15"E, where ~160 m of the formation is exposed. In the stratigraphic charts, sample numbering for the Nazdor section extends from 1 to 72, with samples 1–18 corresponding to the lower part of the Ora Formation and samples 19–72 to the upper part, whereas sample numbering for the Ora section extends from 0 to 40. The text has been revised to match the numbering scheme presented in Figs. 2 and 3.

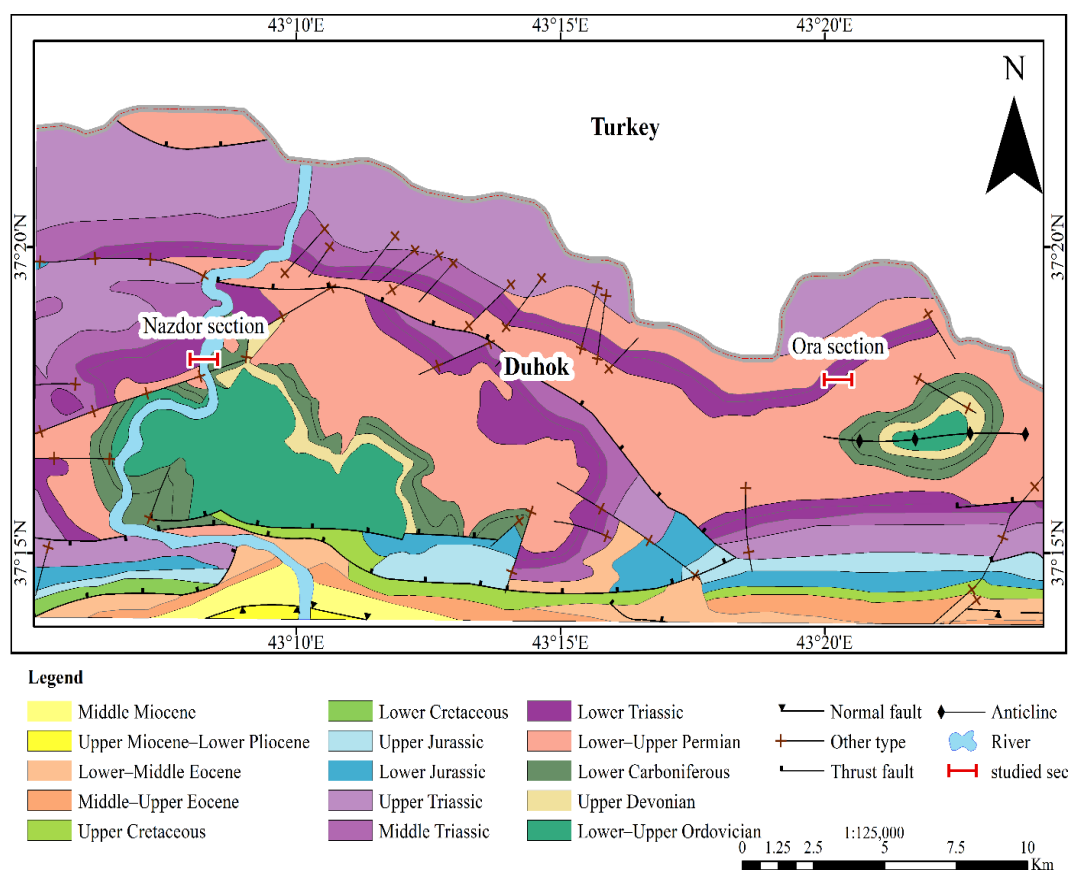


Fig. 1. Geological and location map showing the Ora Formation and other Paleozoic formations within the studied outcrop sections, Ora and Nazdor, Duhok Governorate, northern Iraq (modified from Sissakian and Fouad, 2015)

In the laboratory, standard petrographic thin sections were prepared from the collected carbonates. Bryozoans were investigated primarily in thin section under a binocular/polarizing microscope in transmitted light, which is essential for recognizing diagnostic internal skeletal characters in Palaeozoic stenolaemate bryozoans. The terminology of the morphological characters and the selection of measured features follow established thin-section-based bryozoan systematics.

Taxonomic identification was based on characters observable in tangential, longitudinal, and transverse sections of the samples, including colony growth form, branch diameter, endozone and exozone dimensions, autozoecial aperture size and spacing, wall thickness, diaphragms, vesicular skeleton, lunaria, and accessory structures, such as acanthostyles and mesozoecia, following standard thin-section-based bryozoan systematic practice (Anstey and Perry, 1970; Hageman, 1993; Ernst, 2020).

3. Results

3.1. Bryozoan

Bryozoa are a phylum of complex sessile colonial organisms, most of which live in marine basins, and their long evolutionary history and ecological sensitivity make them useful in palaeoecological and palaeogeographic reconstructions as well as biostratigraphic applications (Tolokonnikova and Ernst, 2017). Their skeletons are chiefly calcitic—most commonly low- to intermediate-Mg calcite—although aragonitic and bimineralic compositions occur in some taxa (Smith et al., 2006; Loxton et al., 2018). They are important constituents of cool-water carbonate producers on open shelves and commonly dominate bryozoan-rich sediments outside the tropics (James and Clarke, 1997; Taylor and Allison,

1998). A bryozoan-dominated grainstone microfacies has been described from the Ora Formation by Al-Shammary and Kurkchi (2015), in which bryozoans constitute the dominant skeletal grains and the groundmass is composed of sparry calcite cement. This interpretation is consistent with the general characteristics of bryozoan-rich carbonate microfacies described by Taylor and Allison (1998) and Flügel (2010).

3.2. Systematic Palaeontology

Systematic descriptions of the Ora Formation bryozoans, following the standard stenolaemate bryozoan practice, where diagnostic characters are defined from oriented sections and described using established morphological terminology (Ernst, 2020).

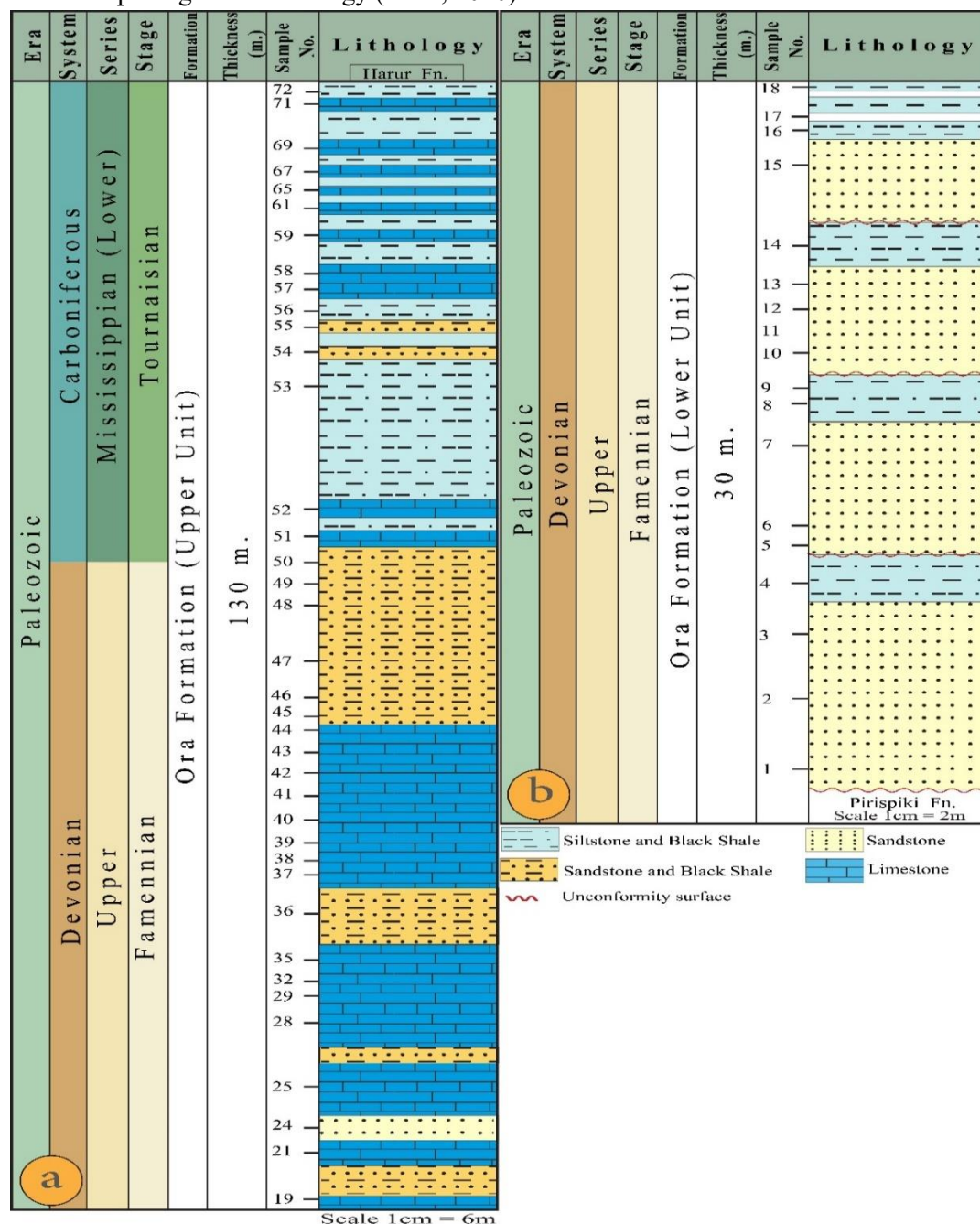


Fig. 2. Lithostratigraphic columnar section of the Ora Formation at the Nazdor section: a) upper part; b) lower part

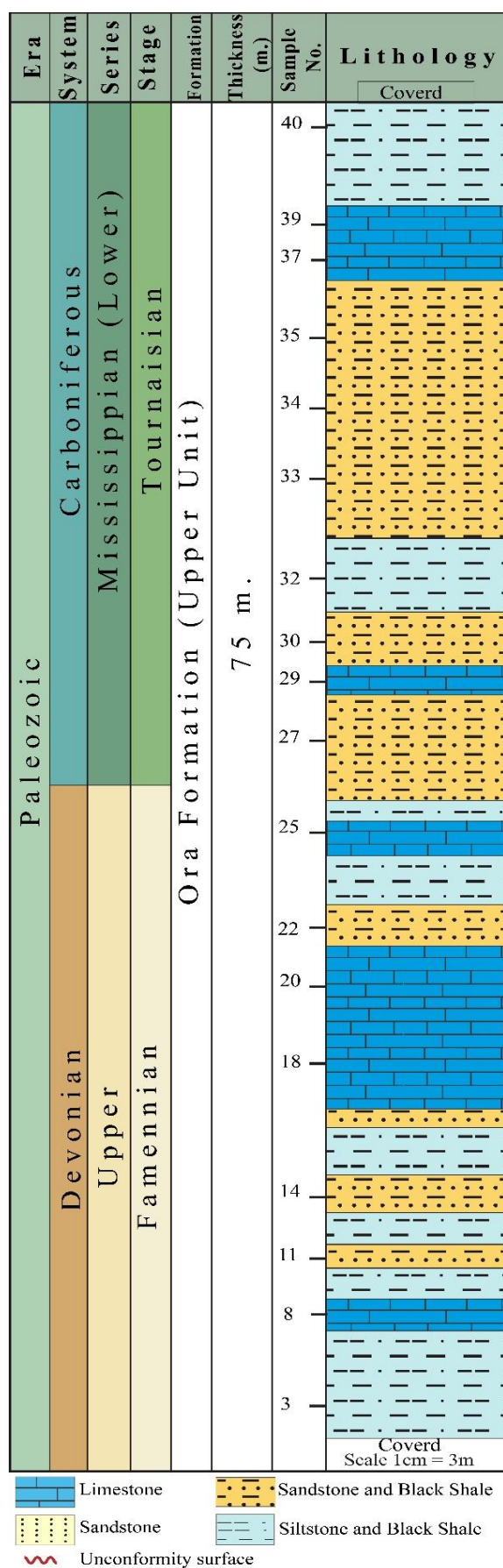


Fig. 3. Lithostratigraphic columnar section of the Ora Formation at the Ora section

For Trepostomes, Cryptostomes, and Fenestrata, morphological terminology is partly adopted from Anstey and Perry (1970) and Hageman (1993), and distances/spacing are treated consistently as centre-to-centre measurements (Ernst, 2020).

3.2.1. Systematic hierarchy

Phylum Bryozoa (Ehrenberg, 1831)

Class Stenolaemata (Borg, 1926)

Order Trepostomata (Ulrich, 1882)

Trepostomata sp. indet.

- Material: Thin sections from the Ora Formation.
- Remarks: Indeterminate trepostome material is retained in open nomenclature where genus-level diagnostic characters cannot be demonstrated with confidence. A comparable treatment was adopted by Tolokonnikova et al., (2015), who illustrated indeterminate trepostomes in branch transverse, longitudinal, and tangential sections.
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, northern Iraq (this study) (Pl.1-A).
- Extra-Iraqi occurrence: Comparable indeterminate trepostome material was reported from the Tournaisian of Belgium (Tolokonnikova et al., 2015).

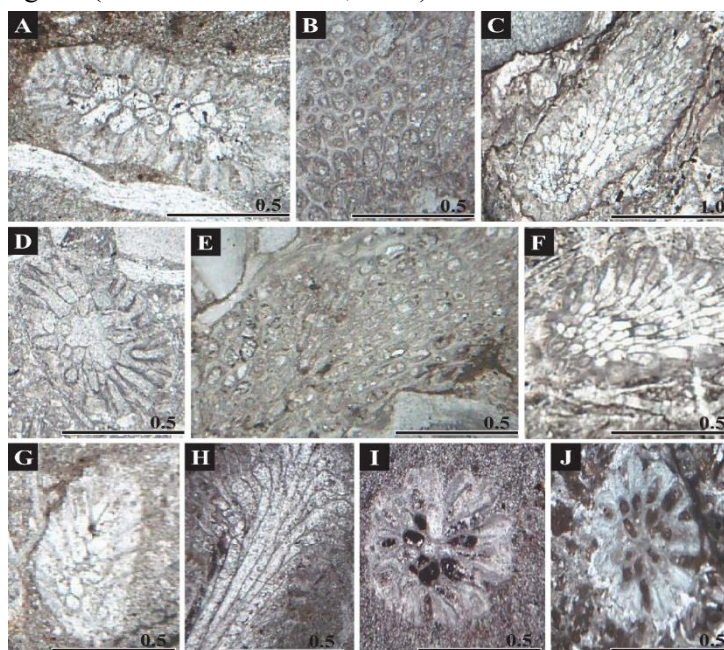


Plate 1. A) *Trepostomata* sp. indet., branch transverse section, Nazdor section, sample No. 53. B–C. *Leioclema polenovi*, Ora section, sample No. 3, B) tangential section showing autozoecial apertures, acanthostyles, and mesozooecia, C) longitudinal section, D) *Neotrematopora inspinosa*, transverse section, Ora section, sample No. 25, E–F) *Nikiforovella* sp., Ora section, sample No. 27, E) tangential section showing autozoecial apertures, metazooecia, and acanthostyles, F) longitudinal section, G–H) *Nikiforovella cavernosa*, longitudinal section, Nazdor section, sample No. 39, I–J) *Nikiforovella gracilis*, Ora section, sample No. 18, I) tangential section, and J) transverse section

Family Heterotrypidae (Ulrich, 1890)

Genus *Leioclema* (Ulrich, 1882)

Leioclema polenovi (Nekhoroshev, 1948)

- Material: Thin sections from the Ora Formation.
Description: In the published Famennian material, this species forms branched colonies with rounded-polygonal to petaloid autozooeccial apertures, the latter resulting from indenting acanthostyles. Mesozooecia are abundant, commonly 6–10 around each aperture, and maculae are absent (Ernst et al., 2025).
- Remarks: The species has a broader stratigraphic history in the literature, but it is explicitly recorded from the Samnuuruul Formation, Upper Devonian, Famennian, in Mongolia. In the present study, *Leioclema polenovi* is compatible with a Famennian comparative framework, but it is not independently age-diagnostic because its broader known range extends back to the Givetian and Lower Frasnian (Ernst et al., 2025).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, northern Iraq (this study) (Pl. 1 B and C).
- Extra-Iraqi occurrence: Samnuuruul Formation, Upper Devonian, Famennian, southwestern Mongolia; older records also extend to the Middle Devonian (Givetian) and Lower Frasnian (Ernst et al., 2025).

Family Trematoporidae (Miller, 1889)

Genus *Neotrematopora* (Morozova, 1961)

Neotrematopora inspinosa (Xia, 1997)

- Material. Thin sections from the Ora Formation.
Description: In the reference material, colonies are branched; mesozooecia are abundant, commonly 6–12 around each autozooeccial aperture; diaphragms are rare to common; and acanthostyles may be present, commonly restricted to the exozone (Ernst et al., 2025).
- Remarks: This species is one of the significant literature-supported links to the Famennian interval because its occurrence is explicitly documented from the Formation of Hongguleleng, Late Devonian, Early Famennian, within Xinjiang, in China, and from the Formation of Samnuuruul, Late Devonian, Famennian, Mongolia (Ernst et al., 2025).
- Occurrence in Iraq. Ora Formation, Ora and Nazdor sections, Duhok Governorate, the northern part of Iraq (the current study) (Pl. 1 D).
- Occurrence within Extra-Iraqi: Formation of Hongguleleng, Late Devonian, Early Famennian, within Xinjiang, in China; Formation of Samnuuruul, Late Devonian, Famennian, Mongolia (Ernst et al., 2025).

Order Cryptostomata (Vine, 1884)

Suborder Rhabdomesina (Astrova and Morozova, 1956)

Family Nikiforovellidae (Gorjunova, 1975)

Genus *Nikiforovella* (Nekhoroshev, 1948)

Type species. *Nikiforovella alternata* (Nekhoroshev, 1948)

- Diagnosis: Branched colonies with autozooeccia diverging at low angles from a distinct median axis. Hemisepta are absent and diaphragms are rare. The laminated autozooeccial walls have dark zooecial boundaries. Metazooecia are few, formed between longitudinally successive apertures, acanthostyles are common to abundant, and longitudinal ridges are absent (Tolokonnikova et al., 2015).
- Occurrence: Devonian to Permian; worldwide (Tolokonnikova et al., 2015; Ernst and Gorgij, 2019; Ernst et al., 2015).

Nikiforovella sp.

- Material: Thin sections from the Ora Formation.

- Description: In the Tournaisian Belgian reference material, the colonies are branched and measure 0.8–1.9 mm in diameter. The exozones are 0.15–0.40 mm wide, whereas the endozones range from 0.5 to 1.1 mm in width. Autozooecia originate spirally from the median axis, show a rhombic outline in transverse sections of the endozone, and bend abruptly within the exozone. The apertures are oval to circular and arranged in regular diagonal rows. Diaphragms are absent, metazooecia commonly occur as two to three between longitudinally successive apertures, and acanthostyles are frequent (Tolokonnikova et al., 2015).
- Remarks: Where species-level diagnosis is not supported by a complete set of oriented sections, the safest treatment is to retain the material as *Nikiforovella* sp. Comparable material is also known from the uppermost Famennian (“Strunian”) of Germany, confirming that the genus ranges across the Devonian–Carboniferous transition (Ernst and Herbig, 2010).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl. 1 E and F).
- Extra-Iraqi occurrence: Tournaisian (Hastarian), Belgium (Tolokonnikova et al., 2015); uppermost Famennian (“Strunian”), Germany (Ernst and Herbig, 2010).

Nikiforovella dinantia (Nekhoroshev, 1948)

- Diagnosis: The colony is branched, with oval to circular autozooecial apertures arranged in regular diagonal rows. Diaphragms are absent, and one to two metazooecia, together with a single acanthostyle, typically occur between successive autozooecial apertures. This species differs from closely related forms by its relatively thicker branches and by the lower number of metazooecia and acanthostyles (Tolokonnikova et al., 2015).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections. This occurrence is compatible with the documented age of the Ora Formation, which spans the latest Devonian to earliest Carboniferous, including the uppermost Famennian–Tournaisian interval (Al-Joboury et al., 2012) (Pl. 2).

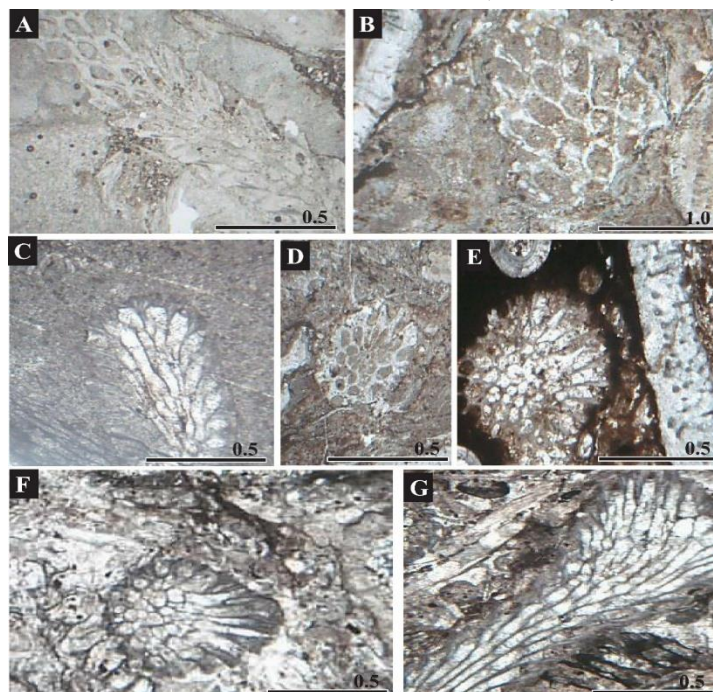


Plate 2. A–G) *Nikiforovella dinantia*. A–B) tangential sections, Nazdor section, sample No. 48; C) longitudinal section, Ora section, sample No. 22; D) cross section, Ora section, sample No. 30; E) oblique section, Nazdor section, sample No. 14; F) cross section, Ora section, sample No. 27; G) longitudinal section, Ora section, sample No. 8

- Extra-Iraqi occurrence: *Nikiforovella dinantia* is best regarded as a Famennian taxon, originally documented from middle to uppermost Famennian strata in southern Belgium. In the context of the present study, this taxon is regarded as consistent with the uppermost Famennian–Tournaisian transitional interval (Tolokonnikova et al., 2015; Ernst and Herbig, 2010).

Nikiforovella cavernosa (Nekhoroshev, 1932)

- Remarks: The uppermost Famennian (“Strunian”) part of the Velbert Formation in Germany contains at least three species of *Nikiforovella*, including *N. cavernosa*. This taxon is therefore suitable as an uppermost Famennian comparative species within the genus (Ernst and Herbig, 2010).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl. 1 G and H).
- Extra-Iraqi occurrence: Uppermost Famennian (“Strunian”), Velbert Formation, Germany (Ernst and Herbig, 2010).

Nikiforovella gracilis (Ernst and Herbig, 2010)

- Remarks: In the same German framework, *N. gracilis* is listed together with *N. cavernosa* and *Nikiforovella* sp., confirming its use as an uppermost Famennian comparative taxon (Ernst and Herbig, 2010).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl. 1 I and J).
- Extra-Iraqi occurrence: Uppermost Famennian (“Strunian”), Velbert Formation, Germany (Ernst and Herbig, 2010).

Family Rhomboporidae (Simpson, 1895)

Rhomboporidae sp.

- Material: Thin sections from the Ora Formation.
- Remarks: The material is retained at the family level because generic assignment cannot yet be supported securely from the available sections. As a comparative framework, rhomboporids are characterized by ramose colonies, oval apertures, regularly thickened exozonal walls, diaphragms in the exozone, one or two acanthostyles on the distal end of each aperture, and numerous paurostyles regularly distributed around the apertures (Ernst and Gorgij, 2019).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl. 3 A and B).
- Extra-Iraqi occurrence: The family is known worldwide from the Devonian to the Permian and therefore is not age-diagnostic at the family level (Ernst and Gorgij, 2019).

Order Fenestrata (Elias and Condra, 1957)

Suborder Fenestellina (Astrova and Morozova, 1956)

Family Fenestellidae (King, 1849)

Genus *Spinofenestella* (Termier and Termier, 1971)

- Diagnosis: Colonies fan-shaped to conical, with straight branches connected by thin dissepiments. Each branch bears two rows of autozoecia. Autozoecial chambers are triangular in deep tangential section, oval beneath the distal tube, and circular in cross section. Proximal hemisepta are absent or poorly developed. The obverse surface is characterised by a low keel bearing a single row of nodes (Tolokonnikova et al., 2015).

Spinofenestella cf. *nodosa*

- Type locality and horizon: Les Ornaïs quarry, Yvoir Formation (Hun Member), Hastarian substage, Tournaisian, Mississippian (Tolokonnikova et al., 2015).

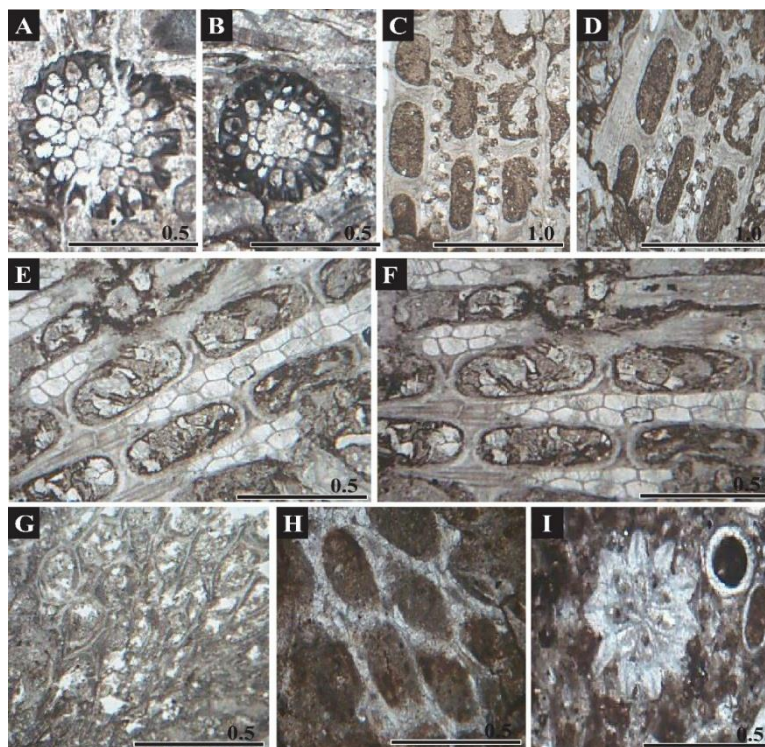


Plate 3. **A–B)** *Rhomboporidae* sp., transverse sections, Ora and Nazdor sections, samples No. 35 and No.68, respectively. **C–D)** *Spinofenestella* cf. *nodosa*, tangential sections, Ora and Nazdor sections, respectively. **E–F.** *Rectifenestella rudis*, tangential sections showing branches, fenestrules, and autozooecial arrangement, Ora and Nazdor sections, samples No. 32 and No.53, respectively. **G–I)** *Saffordotaxis* cf. *spinigerus*, **G–H)** tangential sections, Nazdor section, sample No. 55; **I)** branch transverse section, Ora section, sample No. 39

- **Diagnosis:** Colony reticulate, with a moderately coarse meshwork, narrow dissepiments, and oval to rectangular fenestrules. Autozooecia are arranged in two rows, with local insertion of a third row before bifurcation. In mid-tangential section, the autozooecia are triangular to trapezoidal, and the axial wall is strongly zigzag. Hemisepta are absent. The apertures are circular and bear a single node, with four to seven apertures occurring along each fenestrule length. The keel is low and carries moderately large nodes, whereas large nodes are also present on the reverse surface of the colony (Tolokonnikova et al., 2015).
- **Remarks.** If the Ora material does not preserve the entire combination of nodose keel, zigzag axial wall, and characteristic aperture/fenestrule arrangement, it should be recorded more cautiously as *Spinofenestella* cf. *nodosa*.
- **Occurrence in Iraq:** Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl.3C and D).
- **Extra-Iraqi occurrence:** Tournaisian (Hastarian), Belgium (Tolokonnikova et al., 2015).

Genus *Rectifenestella* (Morozova, 1974)

- **Diagnosis.** Reticulate colonies with fine to moderately robust branches and straight dissepiments; autozooecia are triangular to pentagonal in mid-tangential section; superior hemisepta are present; inferior hemisepta are absent; the keel is narrow with one row of intermediate-sized nodes (Tolokonnikova et al., 2015).
- **Occurrence.** Early Devonian to Late Permian; worldwide (Tolokonnikova et al., 2015; Ernst et al., 2025).

Rectifenestella rudis (Ulrich, 1890)

- Description: In the Belgian Tournaisian reference, this species has branches that are straight and joined with narrow dissepiments, as well as oval to rectangular fenestrules. The autozooecial apertures are circular and bordered by a low peristome with small nodes, whereas the low keel is marked by a single row of alternating smaller and larger nodes. In mid-tangential section, the autozooecia are short and pentagonal to roughly rectangular, the axial wall is strongly to weakly zigzag, hemisepta are absent, and the laminated skeleton contains abundant microstyles (Tolokonnikova et al., 2015).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl.3 E and F).
- Extra-Iraqi occurrence: The Yvoir Formation (Hun Member), Tournaisian (Hastarian), Belgium; also reported from the Viséan of the USA and from the Tournaisian–Viséan of Eurasia (Tolokonnikova et al., 2015).

Genus *Saffordotaxis* (Bassler, 1952)*Saffordotaxis* cf. *spinigerus*

- Type horizon and age: The Yvoir Formation (Hun Member), Hastarian substage, Tournaisian, Mississippian (Tolokonnikova et al., 2015).
- Diagnosis: The colonies are thin and branched, with narrow exozones. Autozooecia originate at angles of 21–37° in the endozone and bend outward in the exozone. The apertures are oval and arranged in diagonal rows, while large aktinostyles form a single row between the autozooecia (Tolokonnikova et al., 2015).
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study) (Pl. 3 G, H and I).
- Extra-Iraqi occurrence: Tournaisian (Hastarian), Belgium (Tolokonnikova et al., 2015).

Order *Cystoporata* (Astrova, 1964)*Cystoporata* gen. et sp. indet.

- Material: Stellate-maculate and rosette-like colony fragments in thin section.
- Remarks: These specimens are retained in open nomenclature because the available sections do not permit a secure generic diagnosis. This is the most defensible treatment for cystoporate-like colony fragments showing rosette-like maculae but lacking a complete diagnostic character set.
- Occurrence in Iraq: Ora Formation, Ora and Nazdor sections, Duhok Governorate, north of Iraq (the current study).
- Extra-Iraqi occurrence: Not specified due to open nomenclature.

3.2.2. Comparative taxa retained within the systematic section

Family Dyscritellidae (Dunaeva and Morozova, 1967)

Genus *Dyscritella* (Girty, 1911)

- Diagnosis: The colonies are dendroid to encrusting and are distinguished by abundant acanthostyles and exilazooecia. The diaphragms are lacking or rare; exilazooecia are separated by thick walls; and rapid wall thickening in the exozone (Ernst and Gorgij, 2019).

Dyscritella cf. *multioporata* (Ernst and Gorgij, 2019)

- Diagnosis: Encrusting and branched colonies; 1–5 exilazooecia per autozooecial aperture; 3–7 acanthostyles per aperture; maculae not observed (Ernst and Gorgij, 2019).

- Occurrence in Iraq: Recorded here only as a comparative taxon for morphological interpretation of exilazooecia and acanthostyles (The current study) (Pl. 4 A).
- Extra-Iraqi occurrence: Siliciclastic Imagh Formation, Carboniferous, Pennsylvanian, central Iran (Ernst and Gorgij, 2019).

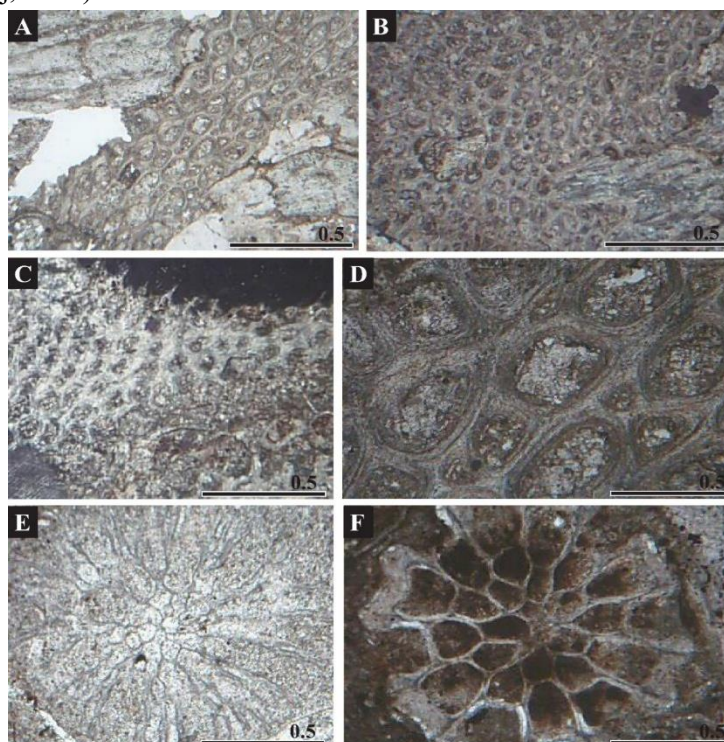


Plate 4. Comparative bryozoan material used for morphological reference. A) *Dyscritella cf. multiporata*, tangential section showing autozooeal apertures, acanthostyles, and exilazooecia, Nazdor section, sample No. 13; B–F) *Dyscritella cf. kalmardensis*, tangential and cross sections illustrating diagnostic comparative features, Ora section, sample No. 13. These specimens are presented for morphological comparison only and are not included as confirmed occurrences within the Ora Formation assemblage

Dyscritella cf. kalmardensis (Ernst and Gorgij, 2019)

- Diagnosis: Branched colonies with narrow exozones; autozooeal diaphragms and exilazooecia are rare; 2–5 acanthostyles occur per autozooeal aperture; maculae were not observed (Ernst and Gorgij, 2019).
- Occurrence in Iraq: The forms compared with *Dyscritella cf. multiporata* and *D. cf. kalmardensis* are retained in open comparative usage in the present study. They are introduced solely to aid morphological interpretation and are not considered confirmed taxonomic records from the Ora Formation. Accordingly, they are excluded from the formal occurrence data and stratigraphic distribution of the Ora and Nazdor sections (Pl. 4 B–F).
- Extra-Iraqi occurrence: Siliciclastic Imagh Formation, Carboniferous, Pennsylvanian, central Iran (Ernst and Gorgij, 2019).

It should be noted that not all recorded bryozoan taxa are equally informative for age determination. Taxa retained at family level or in open nomenclature, such as *Rhomboporidae* sp. and *Cystopora* gen. et sp. indet., are of limited biostratigraphic value and are therefore treated here as supplementary fossil components rather than primary age-diagnostic markers. The distribution of the recorded bryozoan taxa is presented in Table 1 and illustrated in Figs. 4 and 5 for the Ora and Nazdor sections, respectively, in order to show their stratigraphic occurrence within the studied intervals.

Table 1. Occurrence summary table

Taxon	Occurrence in Iraq	Extra-Iraqi occurrence	Reference
<i>Trepostomata</i> sp. indet.	Ora Formation, Ora and Nazdor sections	Tournaisian Belgium comparative material	Tolokonnikova et al., 2015
<i>Leioclema polenovi</i>	Ora Formation, Ora and Nazdor sections	Famennian Mongolia; older Devonian records	Ernst et al., 2025
<i>Neotrematopora inspinosa</i>	Ora Formation, Ora and Nazdor sections	Lower Famennian Xinjiang; Famennian Mongolia	Ernst et al., 2025
<i>Nikiforovella</i> sp.	Ora Formation, Ora and Nazdor sections	Tournaisian Belgium; uppermost Famennian Germany	Tolokonnikova et al., 2015; Ernst and Herbig, 2010
<i>Nikiforovella dinantia</i>	Ora Formation, Ora and Nazdor sections	Famennian, especially middle to uppermost Famennian in southern Belgium.	Tolokonnikova et al., 2015; Ernst and Herbig, 2010
<i>Nikiforovella cavernosa</i>	Ora Formation, Ora and Nazdor sections	uppermost Famennian Germany	Ernst and Herbig, 2010
<i>Nikiforovella gracilis</i>	Ora Formation, Ora and Nazdor sections	uppermost Famennian Germany	Ernst and Herbig, 2010
<i>Rhomboporidae</i> sp.	Ora Formation, Ora and Nazdor sections	Devonian–Permian worldwide family range	Ernst and Gorgij, 2019
<i>Spinofenestella</i> cf. <i>nodosa</i>	Ora Formation, Ora and Nazdor sections	Tournaisian Belgium	Tolokonnikova et al., 2015
<i>Rectifenestella rudis</i>	Ora Formation, Ora and Nazdor sections	Tournaisian Belgium; Viséan USA; Tournaisian–Viséan Eurasia	Tolokonnikova et al., 2015
<i>Saffordotaxis</i> cf. <i>spinigerus</i>	Ora Formation, Ora and Nazdor sections	Tournaisian Belgium	Tolokonnikova et al., 2015
<i>Cystoporata</i> gen. et sp. indet.	Ora Formation, Ora and Nazdor sections	not specified	This study
<i>Dyscritella</i> cf. <i>multioporata</i>	comparative only	Pennsylvanian Iran	Ernst and Gorgij, 2019
<i>Dyscritella</i> cf. <i>kalmardensis</i>	comparative only	Pennsylvanian Iran	Ernst and Gorgij, 2019

4. Discussion

The bryozoan assemblage recorded from the Ora Formation in the Ora and Nazdor sections provides important taxonomic and stratigraphic evidence for understanding the Late Devonian–Early Carboniferous interval in the north of Iraq. The occurrence of stenolaemate bryozoans within carbonate interbeds, particularly in the upper parts of the studied sections, indicates that bryozoans formed a significant component of the benthic carbonate-producing community during deposition of the Ora Formation (Al-Shammari and Kurkchi, 2015; James and Clarke, 1997; Taylor and Allison, 1998). The dominance of trepostome, cryptostome, fenestrate, and cystoporate forms is also consistent with the broad evolutionary and palaeoecological pattern recognised in Paleozoic bryozoan fossils, especially across the Devonian–Carboniferous transition (Tolokonnikova and Ernst, 2017).

The identified taxa show close affinities with Famennian and Tournaisian assemblages previously reported from Belgium, Germany, Mongolia, China, and Iran, suggesting palaeobiogeographic links with broadly comparable northern Gondwanan and peri-Tethyan successions. In particular, the presence of taxa comparable to *Nikiforovella cavernosa*, *N. gracilis*, *Leioclema polenovi*, and *Neotrematopora inspinosa* supports a strong Famennian affinity, whereas *Spinofenestella* cf. *nodosa*, *Rectifenestella rudis*, and *Saffordotaxis* cf. *spinigerus* indicate a closer relationship with Tournaisian fossils (Ernst and Herbig, 2010; Tolokonnikova et al., 2015; Ernst et al., 2025) (Figs. 4 and 5).

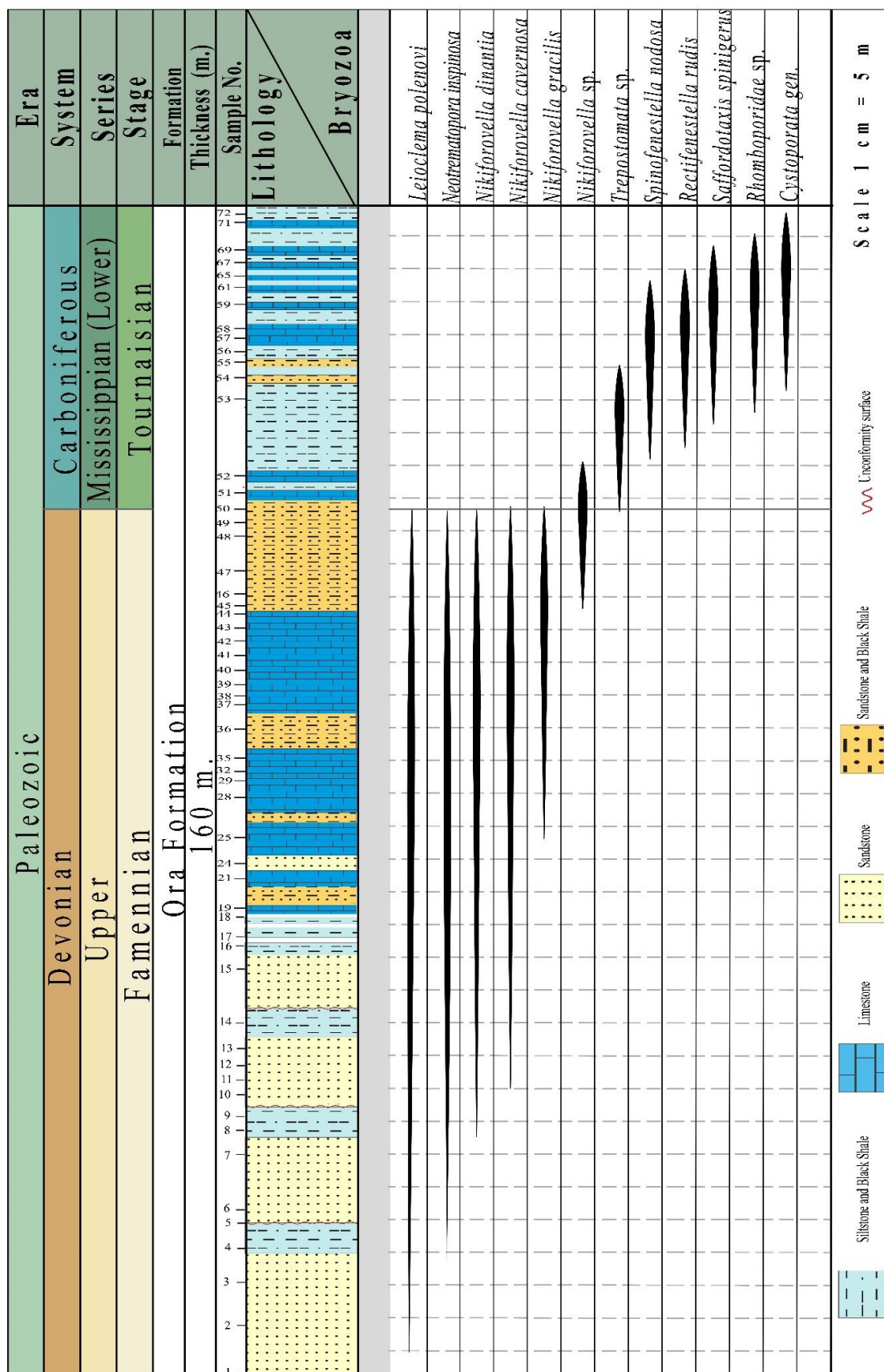


Fig. 4. Distribution of bryozoans within the Ora Formation at the Nazdor section

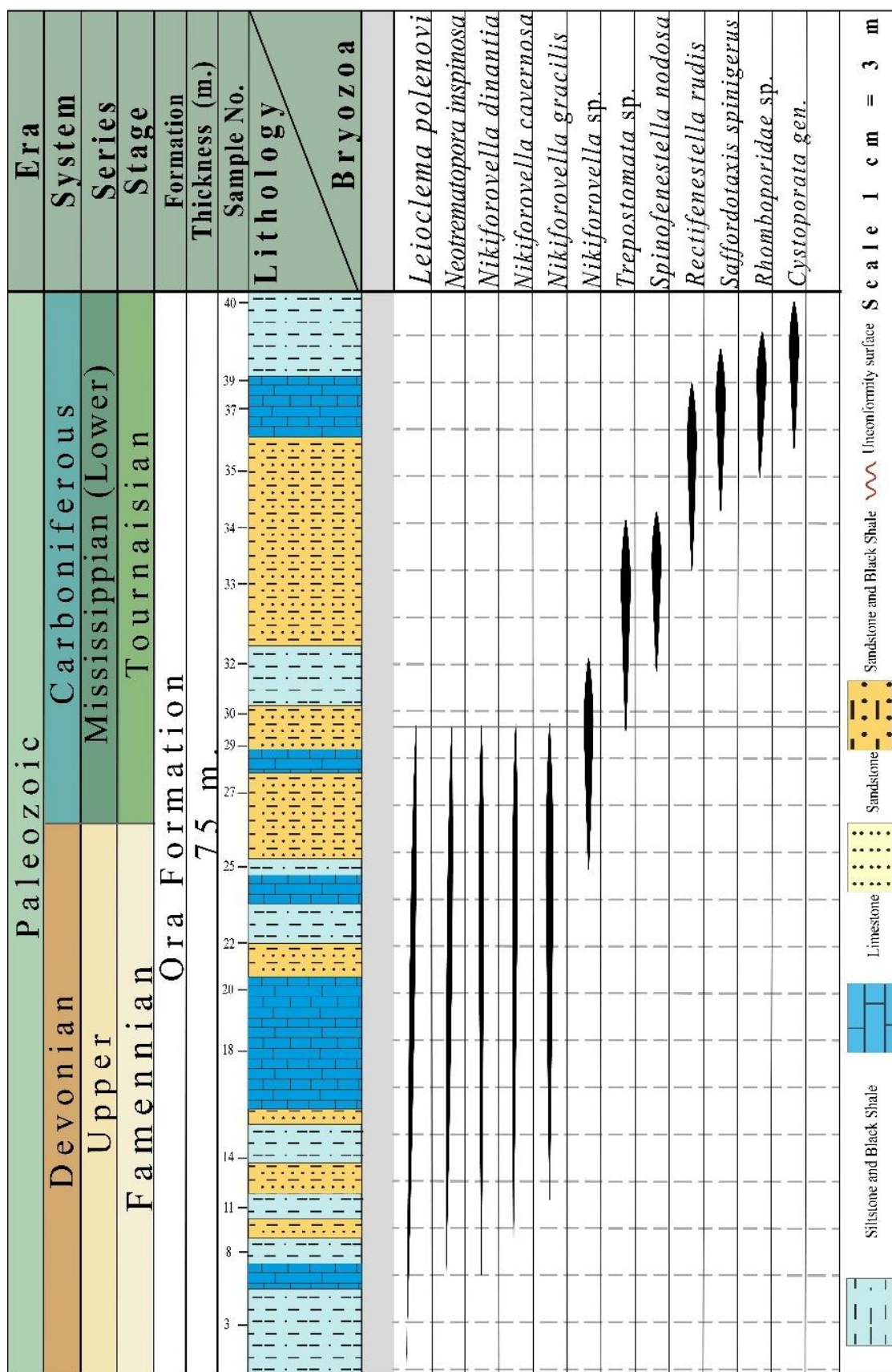


Fig. 5. Distribution of bryozoans within the Ora Formation at the Ora section

However, not all recorded taxa have equal biostratigraphic value, because forms retained in open nomenclature or at higher taxonomic rank, such as *Rhomboporidae* sp. and *Cystoporata* gen. et sp. indet., are more useful as supporting fossil elements than as precise age indicators. Therefore, the assemblage should be interpreted collectively rather than relying on single taxa for age assignment. The restriction of bryozoans mainly to carbonate beds suggests that their distribution was controlled by local depositional conditions, including substrate stability, water energy, and carbonate productivity.

This agrees with previous interpretations of bryozoan-rich packstone and grainstone microfacies in the Ora Formation, which point to shallow-marine carbonate deposition under moderate- to relatively high-energy conditions (Al-Shammary and Kurkchi, 2015; Flügel, 2010). The present study therefore confirms that the Ora Formation contains a more diverse bryozoan fossil assemblage than previously documented and demonstrates that bryozoans can provide a useful supplementary tool for taxonomy, regional correlation, and age assessment of the Famennian–Tournaisian succession in the north of Iraq.

5. Conclusions

The present study documents, for the first time, a bryozoan assemblage from the Ora Formation in the Ora and Nazdor sections of north Iraq and demonstrates that bryozoans represent an important fossil component of the carbonate interbeds within the formation. The assemblage includes taxa belonging mainly to the orders Trepostomata, Cryptostomata, Fenestrata, and Cystoporata, indicating a taxonomically diverse stenolaemate fauna.

The bryozoan assemblage documented from the Ora Formation shows significant affinity with fossils spanning the latest Devonian–earliest Carboniferous transition. In particular, *Neotrematopora inspinosa*, *Leioclema polenovi*, *Nikiforovella cavernosa*, and *N. gracilis* provide the closest comparative links to the Famennian interval, whereas *Spinofenestella* cf. *nodosa*, *Rectifenestella rudis*, and *Saffordotaxis* cf. *spinigerus* show stronger affinity with Tournaisian assemblages. Other taxa retained in open nomenclature or at higher taxonomic rank are considered supportive fossil elements, but they are not treated as independently age-diagnostic. Taken together, the assemblage provides consistent paleontological support for a Famennian–Tournaisian age assignment of the studied succession.

Overall, the bryozoan fossil of the Ora Formation establishes an important foundation for future systematic, biostratigraphic, palaeoecological, and regional correlation studies and highlights the significance of this unit as a key reference succession in northern Iraq.

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Declaration of Competing Interest

No potential conflict of interest relevant to this article was reported.

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Data Availability

All data generated or analysed during the current study are included in this article and its figures, tables, and plates. Additional information is available from the corresponding author upon reasonable request.

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